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The Long-term Problem with Electric Vehicle Batteries: A Policy Recommendation to Encourage Advancement for Scalable Recycling Practices

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The Long-term Problem with Electric Vehicle Batteries: A Policy Recommendation to Encourage Advancement for Scalable Recycling Practices

By: Lauren Fricke[*]

I. INTRODUCTION

Around 1890, the first successful electric car debuted in the United States. William Morrison, a chemist from Des Moines, Iowa, invented a six-passenger vehicle powered only by electricity that had a maximum speed of fourteen miles per hour.[1] By 1900, electric cars accounted for approximately one-third of all vehicles on the road in the United States.[2] Americans were experimenting with steam, gasoline, and electricity to power vehicles for transportation.[3] Though a historic source of power for factories and trains, steam was impractical for personal vehicles because steam-engines needed time to heat up and had limited range due to the need for water refills and heavy construction.[4] Electric vehicles (EVs) were introduced at the same time as gasoline power vehicles.[5] Gasoline powered vehicles presented challenges such as noise, exhaust, and the added difficulty that they needed to be started with a hand crank.[6] Electric cars did not have the issues related to steam or gasoline cars which created a high demand in the early 1900s.[7] Thomas Edison expressed that electric vehicles were the superior technology and worked to perfect the EV battery.[8] However, what swayed consumers towards gasoline-powered vehicles was the introduction of the Ford Model T into the market in 1908.[9]

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[1]*The History of the Electric Car*, DEP'T OF ENERGY (Sept. 15, 2014), https://www.energy.gov/articles/history-electric-car [https://perma.cc/7DT9-WBQT].

[2] *Id.*

[3] *Id.*

[4] *Id.*; Kat Eschner, *Why Did People Think Steam-Powered Cars Were a Good Idea?*, SMITHSONIAN MAG. (Jan. 26, 2017), https://www.smithsonianmag.com/smart-news/why-did-people-think-steam-powered-cars-were-good-idea-180961872/ [https://perma.cc/D3KE-NQXQ**].**

[5] Dep't of Energy, *supra* note 1.

[6] *Id.*; *Why Most Motorists Preferred Gasoline Cars*, NAT'L MUSEUM OF AMERICAN HIST. (2020), https://americanhistory.si.edu/automobile-energy-choice/why-gasoline [**https://perma.cc/J62K-JTVX]**

[7] *The History of the Electric Car*, DEP'T OF ENERGY (Sept.15, 2014), https://www.energy.gov/articles/history-electric-car [**https://perma.cc/7DT9-WBQT].**

[8] *Id.*

[9] *Id.*

The Model T was more affordable and accessible than the electric vehicles at the time.[10] In 1912, a gasoline-powered car cost $650 in contrast to an EV which cost significantly more at $1,750.[11] In addition, the invention of the electric starter for gasoline-powered vehicles eliminated the need for the hand crank start, which added to the preference of gasoline over electricity as a power source for vehicles.[12]

Around fifty years later, due to skyrocketing oil prices and gasoline shortages, Congress passed the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976. This gave the Energy Department the power to support research and development of electric and hybrid vehicles and created a surge in innovation exemplified by the American Motor Company producing electric delivery jeeps for the United States Postal Service and NASA using an electric rover as the first manned vehicle on the moon in 1971.[13] However, the consumers resisted the adoption of electric vehicles due to low maximum speeds and short driving ranges before the need to recharge.[14]

In the 1990s, legislation again spurred innovation and increased interest in EVs. In 1990 Congress passed the Clean Air Act Amendment and two years later the Energy Policy Act.[15] With these new policies, automakers worked to increase the mileage range of electric vehicles to around 60 miles.[16] Most notably, General Motors (GM) created the EV1, a fully electric car with a range of 80 miles, with the ability to accelerate from zero to fifty miles per hour in seven seconds.[17]

The downfall of the EV1 is perhaps the most notable example of how state legislation spurred innovation in the electric vehicle and the lack of federal support and federal legislation lead to the downfall of the electric vehicle during the late 2000s.[18] In 1990, the California Air Resources Board (CARB) passed the zero-emissions vehicle mandate, which required ten percent of all new car sales in California to be electric cars by the year 2001.[19] GM created and began leasing the EV1 to Californians in response to this mandate and it became a beloved car by many in the state of California.[20] Unfortunately, GM, along with several other major car companies opposed the legislation and filed multiple suits against CARB.[21] With additional pressure from the oil industry and the Bush administration, CARB reversed the mandate.[22] Following the

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[10] *Worth the Watt: A Brief History of the Electric Car, 1830-Present*, CAR AND DRIVER (Mar. 15, 2018), https://www.caranddriver.com/features/g15378765/worth-the-watt-a-brief-history-of-the-electric-car-1830-to-present/ [https://perma.cc/XMA9-NRCU].
[11] Dep't of Energy, *supra* note 1.
[12] *Why Most Motorists Preferred Gasoline Cars*, *supra* note 6.
[13] Dep't of Energy, *supra* note 1.
[14] *Id.*
[15] *Clean Air Act Overview*, U.S. ENV'T PROT. AGENCY (Oct. 13, 2020), https://www.epa.gov/clean-air-act-overview/1990-clean-air-act-amendment-summary [https://perma.cc/TY5U-5W4B]; Energy Policy Act of 2005. H.R.6. 109th Congress (2005-2006).
[16] Dep't of Energy, *supra* note 1.
[17] *Id.*
[18] WHO KILLED THE ELECTRIC CAR? (Electric Entertainment 2006).
[19] *Id.*
[20] *Id.*
[21] *Id.*
[22] *Id.*

reversal, GM systematically pulled every EV1 off the streets when the leases expired.[23] GM claimed that there was no demand for the EV1 and therefore they needed to shift their focus to other revenue generating vehicles, such as the Hummer.[24] However, GM was likely taking a defensive position as if they were to effectively market the EV1, they would be indirectly saying that their gasoline powered cars were bad for the environment and generally a bad choice.[25] Additionally, GM would be losing revenue from parts sales from the combustion engine being replaced by a simpler battery. This stance seemed to be universal across all auto manufacturers.[26] As a result, almost 5000 electric cars were destroyed by all major auto manufacturers, including GM.[27] This shows that auto manufacturers will not innovate green technology outside of their immediate financial interest without federal incentives and regulation.[28] Had the federal government stepped in to assist California instead of backing oil companies and auto manufactures, the EV1 might have survived, and electric vehicle innovation might be farther along today.[29]

Two pivotal events driven by legislation sparked today's interest in EVs. First, in 1997 Toyota introduced the Prius, which became the first mass-produced hybrid electric vehicle in the world.[30] The Prius used a nickel metal hydride battery which was supported by research from the United States Department of Energy.[31] Second, Tesla Motors invented a luxury electric sports car that had a range of 200 miles.[32] Tesla's innovation was spurred by a loan from the Department of Energy for $465 million to build a manufacturing facility in California.[33]

Tesla's subsequent success accelerated the innovation of large auto manufacturers to compete in the market.[34] In 2010, Chevrolet introduced the first mass-produced, plug-in hybrid, the Volt.[35] Shortly after, Nissan released the LEAF, a competing affordable electric vehicle. The greatest challenge that automakers faced at this point was infrastructure for consumers to charge their vehicles when away from their homes.[36]

In 2009, policymakers again stepped in to facilitate innovation, when Congress enacted the Recovery Act enabling the Department of Energy to invest more than $115 million to aid in building nation-wide charging stations.[37] In addition, the Department of Energy assisted in the development of the lithium-ion battery resulting in the improvement of

[23] *Id.*
[24] *Id.*
[25] *Id.*
[26] *Id.*
[27] *Id.*
[28] *Id.*
[29] *Id.*
[30] Dep't of Energy, s*upra* note 1.
[31] *Id.*
[32] *Id.*
[33] *Id.*
[34] *Id.*
[35] *Id.*
[36] *Id.*
[37] *Id.*; *The Recovery Act*, OBAMA WHITE HOUSE, https://obamawhitehouse.archives.gov/recovery [https://perma.cc/PQ3P-ZX7F].

battery range, power, durability, and subsequently cutting the battery cost by fifty percent.[38] Further, in 2012 President Obama launched the EV Everywhere Grand Challenge which brought together American scientists, engineers, and businesses with the goal of making electric vehicles comparable in price to gasoline-powered vehicles by 2022.[39]

With the growing popularity of electric vehicles, the demand for lithium ion (Li-ion) batteries, which are the dominant energy source for electric vehicles, is skyrocketing.[40] By default, this means a growing demand for the raw materials needed to manufacture these complex batteries such as lithium, cobalt, and nickel.[41] Economic, environmental, and political supply chain factors bring into question the sustainability of these batteries as a solution to the issues surrounding gasoline powered transportation, creating a need for large scale Li-ion battery recycling.[42] By 2030, 140 million EVs are predicted to be on the road worldwide.[43] In that time, Eleven million metric tons of Li-ion batteries are expected to reach the end of their service lives.[44] With less than five percent of all Li-ion batteries in the European Union and the United States are being recycled there is clearly room for growth. In order to incentivize the move toward greater recycling practices, legislation must be passed to encourage companies to recycle expired EV batteries and work toward innovation in the field.[45] Government policy will aid in avoiding a buildup of used batteries sitting in landfills along with slowing the depletion of rare earth minerals while improving a potentially environmentally friendly industry that saves United States citizens and the United States government money on gasoline.

This article will first discuss how Li-ion batteries work and the current recycling processes available. Next it will analyze the problems associated with Li-ion batteries and the multiple benefits associated with Li-ion battery recycling. Then this article will address the challenges associated with Li-ion battery recycling and the need for research and innovation in the field. Next, it examines the current regulations in place for Li-ion recycling and proposed legislation. Finally, this article will outline current legislation in the European Union and Japan and propose a new regulatory scheme for the U.S. that will best achieve the policy goals of environmental protection, economic gain, and supply chain safety.

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[38] *Id.*
[39] *Id.*
[40] Alexandre Beaudet, *Key Challenges and Opportunities for Recycling Electric Vehicle Battery Materials*, SUSTAINABILITY (2020), https://www.mdpi.com/2071-1050/12/14/5837/htm [**https://perma.cc/SKA5-KNX3].**
[41] *Id.*
[42] *Id.*
[43] Mitch Jacoby, *It's Time To Get Serious About Recycling Lithium-Ion Batteries*, CHEM. & ENG'G NEWS (July 14, 2019), https://cen.acs.org/materials/energy-storage/time-serious-recycling-lithium/97/i28 [https://perma.cc/F48S-HUMU].
[44] *Id.*
[45] *Id.*

II. LI-ION BATTERIES EXPLAINED

A. General Structure

To understand the necessity for innovation in Li-ion battery recycling as well as the challenges recycling presents for legislation, the complexity of the modern Li-ion battery must be understood. Modern Li-ion batteries are complex structures composed of numerous cells grouped together into modules and fitted into a large pack.[46] "Each cell contains a cathode, anode, separator, and electrolyte."[47] Within the modules, cells are each connected to wire circuits.[48] An electronic battery system (BMS) connects to the circuitry of the pack.[49] "The configuration, size, shape of the cells, modules, and packs differ from manufacturer to manufacturer, and even from model to model within manufacturers."[50] Additionally, within the cells, the chemical compositions of the active materials vary from manufacturer to manufacturer.[51] These compositions are constantly changing and may never standardize.[52]

Cathodes exist on each cell within the batteries and use the largest number of raw materials of any part of the battery. Between thirty percent and forty percent of Li-ion battery weight comes from valuable cathode material.[53] Cathodes are negatively charged electrodes through which electrons enter a cell.[54] Cathode material can consist of a variety of metal oxides such as lithium cobalt oxide, lithium nickel/manganese/cobalt oxide, or lithium-ion phosphate.[55]

In addition to cathodes, the rest of the battery includes numerous resources and recyclable materials. "Anodes usually contain graphite, PVDF, and copper foil."[56] Separators are made up of plastic films which usually consist of polyethylene or polypropylene.[57] These separators surround the electrodes, to keep the battery from short circuiting.[58] Lastly, the electrolyte is typically lithium hexafluorophosphate dissolved in ethylene carbonate and dimethyl carbonate.[59] Once the components are assembled, they are then packed in a plastic or aluminum case.[60]

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[46] Linda Gaines, *Lithium-Ion Battery Recycling Processes: Research Towards a Sustainable Course*, 17 SUSTAINABLE MATERIALS AND TECH. (2018), https://www.sciencedirect.com/science/article/pii/S2214993718300629?casa_token=8VSYhqZh2mEAAAA:cmFxc0wbRwsgSthY3ugSa_xGtMYR3wS983FkNBDFNlEDWDUi3gtHZzbrlEqQCaV6J-eg35giGc [https://perma.cc/558F-Q4LY].

[47] Jacoby, *supra* note 43.

[48] Gaines, *supra* note 46.

[49] *Id.*

[50] *Id.*

[51] Linda Gaines, The Future of Automotive Lithium-Ion Battery recycling: Charting a Sustainable Course, 1-2 SUSTAINABLE MATERIALS AND TECH. (2014).

[52] *Id.*

[53] Jacoby, *supra* note 43.

[54] *Cathode*, ENCYCLOPEDIA BRITANNICA, https://www.britannica.com/technology/cathode [https://perma.cc/SDT2-RSW7] (last visited Apr. 15, 2021).

[55] Gaines, *supra* note 46.

[56] Jacoby, *supra* note 43.

[57] *Id.*

[58] *Id.*

[59] *Id.*

[60] *Id.*

EV Li-ion batteries have two stages of life. The first stage of life for an EV battery is first time use in an electric vehicle.[61] Most commercial EV manufacturers provide an eight-year warranty to cover this stage of the battery.[62] Occasionally, early failures happen during this stage at which point the batteries are either remanufactured and reinstalled or replaced by a new battery.[63] "Most battery manufacturers mark the end of the EV use stage when available battery capacity fades to seventy to eighty percent of its normal maximum capacity."[64] At this point, the battery enters the second stage which is end of use.

Currently EV batteries at the end of use stage are either broken down and the metals and other alloys within them are recycled individually or the batteries are directly recycled into another product to be used for less demanding energy storage.[65] If the battery is repurposed, this is known as the second use application stage.[66] This stage can last for a variable amount of time depending on the second use until the battery finally reaches the end of life, at which point ideally the battery is then recycled.[67] The complexity of the batteries and the use of raw earth materials present challenges for efficient, scalable, and economically viable recycling practices.

III. CURRENT RECYCLING PRACTICES

The current recycling efforts in Europe and Asia are leagues ahead of the efforts in the United States.[68] As of 2016, European countries accounted for fifty percent of the world's recycling capacity and China alone accounted for thirty-three percent.[69] While strict environmental regulations push innovation in the European Union (EU), the economic value of recovered materials pushes the innovation in China.[70] However, in 2019, China implemented new regulation to include a recovery rate requirement of no less than ninety-seven percent for nickel, cobalt, and manganese.[71] Three main Li-ion recycling practices are currently used around the world including the EU and China: pyrometallurgical, hydrometallurgical, and direct recycling.[72] Each will be addressed in turn.

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[61] Mohammad Abdelbaky et al., *Forecasting the EU Recycling Potential for Batteries from Electric Vehicles*, 90 PROCEDIA CIRP (2020), https://www.sciencedirect.com/science/article/pii/S2212827120302808 [https://perma.cc/RF2J-BZHA].
[62] *Id.*
[63] *Id.*
[64] *Id.*
[65] *Id.*
[66] *Id.*
[67] *Id.*
[68] Darlene Steward et al., *Economics and Challenges of Li-Ion Battery Recycling from End-of-Life Vehicles*, PROCEDIA MFG. 33, 277 (2019), https://www.nrel.gov/docs/fy19osti/71350.pdf [https://perma.cc/T74M-CW4R].
[69] *Id.*
[70] *Id.*
[71] *China Launches NEV Battery Recycling Regulations*, ARGUS MEDIA (Jan. 6, 2020), https://www.argusmedia.com/en/news/2045403-china-launches-nev-battery-recycling-regulations[https://perma.cc/2K5Y-SCPW].
[72] Steward, *supra* note 68.

A. Pyrometallurgical Recycling

Several large smelting facilities in the United States are used for pyrometallurgical recycling.[73] Pyrometallurgical recycling involves first dismantling Li-ion batteries to the modular level.[74] After dismantling, the pieces are introduced into a high-temperature shaft furnace along with an agent to form slag.[75] Electrolyte and plastic materials from the batteries burn off in the furnace, creating some of the energy used for the smelting process, which produces an alloy of copper, cobalt, nickel, and ion.[76] The slag created from the process contains the valuable raw cathode materials of lithium, aluminum, silicon, calcium, iron, and manganese.[77]

The issue with pyrometallurgical recycling is that it is neither economical, nor energy efficient.[78] The process recovers cobalt, nickel, and copper, but burns lithium, aluminum, and any organic compounds, wasting materials that could be recycled through other methods.[79] Creating potentially toxic by-products, such as emissions of fluorine compounds, which must be remedied with gas cleanup provisions.[80] These provisions are costly, especially when all of the materials are unusable.

However, pyrometallurgical recycling does have some benefits.[81] Pyrometallurgy is flexible and "applicable to any battery chemistry."[82] First, there is no sorting or pretreatment required with the other hydrometallurgical and direct recycling.[83] Second, pyrometallurgy yields a high recovery of metals. Finally, the practice is a proven technology that can be implemented on a large scale through existing facilities.[84]

B. Hydrometallurgy Recycling

In the hydrometallurgy process, batteries are crushed, and then the component is sorted to recover steel, copper foil, and aluminum foil.[85] This process exploits the high solubility of transition metals and lithium in acid.[86] Hydrometallurgy also gives the possibility of electrolyte recovery.[87]

The advantage of hydrometallurgy over pyrometallurgy is the high recovery rate for lithium, which is performed through precipitation after leaching solution purification.[88] Although relatively new, this process is generally seen as one of the most promising approaches for battery

[73] *Id.*
[74] Gaines, *supra* note 51, at 5.
[75] *Id.*
[76] *Id.*
[77] *Id.* at 6.
[78] *Id.*
[79] Jacoby, *supra* note 43.
[80] Gaines, *supra* note 51, at 6.
[81] Beaudet, *supra* note 40, at 6, Table 1.
[82] *Id*.
[83] *Id*.
[84] *Id*.
[85] *Id*. at 5.
[86] *Id*.
[87] *Id*.
[88] *Id*.

recycling.[89] The advantages include: applicability to any battery chemistry and configuration; flexible separation and recovery processes for specific material targeting; high recovery rates; high purity products; energy efficiency; and no air emissions.[90] There are disadvantages to this process, including the fact that it has a high operating cost, and through the process, no anode materials, including graphite, are recoverable.[91] Additionally, the crushing requirement causes safety concerns for employees in the facility.[92]

C. Direct Recycling

Direct recycling takes the least amount of additional processing.[93] Through direct recycling, breached discharged cells are placed into a container with carbon dioxide.[94] Then, the temperature and pressure in the container are raised to bring the carbon dioxide above its critical point.[95] The carbon dioxide extracts the electrolyte from the cells and the carbon and is removed.[96] The electrolyte separates from the gaseous CO2, and after further processing, can be recycled for use in batteries if determined to be economical.[97] The cells, devoid of electrolyte, undergo pulverization or other size-reduction steps, possibly in the absence of water or oxygen to avoid contamination of materials.[98] Subsequently, the cell components are separated through techniques that exploit differences in electric conductivity, density, or other properties.[99] Finally, the cathode materials may need to undergo re-lithiation before reuse in batteries.[100]

What is advantageous about this process is that almost all of the battery components can be recovered and reused after further processing.[101] Most importantly, cathode materials can be salvaged through direct recycling, regardless of type.[102] While there are questions surrounding the performance of the recycled cathode material, this is an area that should be investigated.[103] Additional major drawbacks of direct recycling include: the requirement of complex mechanical pre-treatment and separations; the mixture of cathode materials which could reduce the value of the recycled product; the lack of development of the regeneration processes; and the fact that it is not currently scaled to an industrial level.[104]

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[89] *Id.*
[90] *Id.*
[91] *Id.*
[92] *Id.*
[93] Gaines, *supra* note 52, at 6.
[94] *Id.*
[95] *Id.*
[96] *Id.*
[97] *Id.*
[98] *Id.*
[99] *Id.*
[100] *Id.*
[101] *Id.*
[102] *Id.*
[103] *Id.*
[104] Beaudet, *supra* note 41, at 6, Table 1.

IV. BENEFITS TO LI-ION RECYCLING

Even though all current popular methods of Li-ion recycling have economic and scalability drawbacks, the benefits which could be achieved through Li-ion battery recycling innovation are numerous, making innovation worthwhile corporately, nationally, and individually. The main advantages of Li-ion battery recycling innovation are environmental, economic, and geopolitical.

A. Environmental Benefits

Batteries have negative environmental consequences after their useful lives and before manufacturing that can be remedied through recycling.[105] First, recycling innovation will likely reduce the amount of hazardous material entering landfills.[106] Metals such as cobalt, manganese, and lithium fluorine solution can leak out of the casings of batteries in landfills and contaminate the soil and groundwater.[107] Once these substances leak, they threaten ecosystems and human health.[108]

Before manufacture, recycling likely will lessen the reliance on mining virgin material as companies will be able to reuse battery elements salvaged through recycling, slowing the depletion of rare earth metals and decreasing the negative environmental impacts of mining processes.[109] For example, metal-sulfide ore is occasionally used for the processing of certain battery metals after mining.[110] This practice emits Sulphur oxides into the air, which can lead to acid rain.[111] Additionally, lithium mining uses 750 tons of mineral-rich bring to produce one ton of lithium.[112] The production from the brine involves drilling a hole in a salt flat and pumping the mineral solution to the surface.[113] This method results in water table depletion for surrounding communities.[114] This is exemplified in Chile, where lithium mining practices consume sixty-five percent of the Salar de Atacama region's water.[115]

Additionally, less reliance on mining could slow the depletion of raw materials.[116] While lithium and nickel reserves are likely adequate to sustain the growth of the battery industry, models show that battery manufacturing could decrease global cobalt reserves by over ten percent through 2050.[117] Unless new recycling practices are discovered or current

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[105] *Id.* at 5.
[106] *Id.*
[107] *Id.*
[108] *Id.*
[109] *Id.*
[110] *Id.*
[111] *Sulfur Dioxide Basics*, U.S. ENV'T PROT. AGENCY (Jan. 28, 2021), https://www.epa.gov/so2-pollution/sulfur-dioxide-basics [**https://perma.cc/5364-HEB8**].
[112] Gavin Harper et al., *Recycling Lithium-Ion Batteries from Electric Vehicles*, 575 NATURE (Jan. 21, 2019), https://www.nature.com/articles/s41586-019-1682-5 [**https://perma.cc/Q2CN-6QD9**].
[113] *Id.* at 76.
[114] *Id.*
[115] *Id.*
[116] Jacoby, *supra* note 43.
[117] *Id.*

practices improved, mining will continue to deplete cobalt reserves at the same rate or faster.[118]

B. Economic Benefits

The primary economic benefit of recycling Li-ion batteries is that the recovered materials could be recycled into new batteries, lowering manufacturing costs for companies and subsequently lowering consumer purchase prices.[119] The price of raw materials used in Li-batteries accounts for more than half of the battery cost.[120] The most expensive metals in the battery are cobalt and nickel, which fluctuate significantly in price.[121] In 2019, the price of cobalt was approximately $27,500 per metric ton as opposed to a year prior to 2018 when the price exceeded $90,000 per metric ton.[122]

On a local scale, recycling plants will stimulate local economies generating revenue, taxable income, and jobs.[123] Since there is a high cost of transporting used batteries, companies have an incentive to keep recycling locally.[124] For individuals and countries, new recycling facilities could create lasting jobs.[125] With this practice likely being a major industry of the future, there is an incentive to innovate and excel in the industry now to create jobs that will last for years to come.[126]

C. Geopolitical Benefits

Although many EV car manufacturers are working to find ways to decrease the use of cobalt in their batteries, most EV Li-ion batteries still contain cobalt. In 2019, fifty percent of the world's cobalt production was sourced from the Democratic Republic of the Congo.[127] Sadly, cobalt mining in the Democratic Republic of the Congo is tied to armed conflict, illegal mining, human rights abuses, and harmful environmental practices.[128]

An estimated thirty percent of the Congo's cobalt uses the unregulated practice of employing "artisanal" miners who dig up the cobalt by hand.[129] These miners are typically not formally trained and often include children.[130] In 2019, Apple, Google, Tesla, and Microsoft were among the companies named in a case filed by the International Rights Advocates on behalf of 14 Congolese families seeking damages

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[118] *Id.*
[119] *Id.*
[120] *Id.*
[121] *Id.*
[122] *Id.*
[123] Beaudet, *supra* note 40, at 3.
[124] *Id.*
[125] *Id.*
[126] *Id.*
[127] Jacoby, *supra* note 43.
[128] *Id.*
[129] Henry Sanderson, *Congo, Child Labour, and Your Electric Car*, FIN. TIMES (July 6, 2019), https://www.ft.com/content/c6909812-9ce4-11e9-9c06-a4640c9feebb [https://perma.cc/M3RW-7NLE].
[130] *Id.*

over deaths and injuries of child miners.[131] The lawsuit alleged that the companies knowingly used cobalt in their products and could be linked to child labor.[132]

Carmakers face a dilemma to meet the growing demand for Li-batteries and the consequent need for cobalt.[133] If carmakers step in to regulate conditions in the Democratic Republic of the Congo, they face risks from corruption and numerous foreign parties involved competing for the resource; however, without the cobalt, carmakers will not be able to manufacture the Li-ion batteries they need.[134] Recycling batteries could help decrease the dependence on this problematic source and help improve the security of the Li-ion battery supply chain.[135]

V. CURRENT AND PROPOSED REGULATORY SCHEMES

A. Current Legislation

Currently, there are no specific federal-level regulations regarding the recycling of large-format Li-ion batteries.[136] While some might argue that this is good for recyclers who would have no restrictions in the design process, this poses a significant issue due to the high likelihood that restrictive regulations will be imposed after building a recycling facility, making it unusable.[137] Although there are no regulations, there are several voluntary consortiums addressing recycling and design for Li-ion recycling.[138] Additionally, state laws are implementing Extended Producer Responsibility for recycling and design for recycling along with similar state programs addressing mercury switches and tires.[139] Extended Producer Responsibility makes the producer responsible for the battery after-sale, encouraging producers to invest in recycling programs and innovate to make products easier to recycle as they are now responsible for their products after the products leave production.[140] Unfortunately, the lack of uniformity due to the lack of federal legislation leads to difficulties creating scalable innovations, which would generally be compliant across the United States.[141]

In 2019 the Department of Energy demonstrated federal awareness of the need for advancement by announcing a $5.5 million, multi-phased Lithium-Ion Battery Recycling Prize.[142] The prize is

[131] *Top Tech Firms Sued Over DR Congo Cobalt Mining Deaths,* BBC NEWS (Dec. 16, 2019), https://www.bbc.com/news/world-africa-50812616 [https://perma.cc/T7CF-W6AY]; Doe v. Apple Inc., Case No. 1:19-cv-03737 (D.D.C. Dec. 16, 2019).
[132] *Id.*
[133] Sanderson, *supra* note 129, at 3.
[134] *Id.*
[135] Jacoby, *supra* note 43.
[136] Darlene Steward et al., *Economics and Challenges of Li-Ion Battery Recycling from End-of-Life Vehicles*, PROCEDIA MFG. 33, 276 (2019), https://www.nrel.gov/docs/fy19osti/71350.pdf [https://perma.cc/T74M-CW4R].
[137] *Id.*
[138] *Id.*
[139] *Id.*
[140] *Id.*
[141] *Id.*
[142] *Lithium-Ion Battery Recycling Prize,* U.S. DEP'T OF ENERGY, https://americanmadechallenges.org/batteryrecycling/ [https://perma.cc/5JU3-5FY7].
[142] Battery and Critical Mineral Recycling Act of 2020, S.3356, 166th Cong. (2020).

designed to incentivize American entrepreneurs to develop and demonstrate processes that have the potential to profitably capture ninety percent of all discarded or spent lithium-based batteries in the United States for the recovery of key materials for re-introduction into the supply chain.[143] However, as exemplified by the history of electric vehicle innovation, financial incentives must be coupled with federal legislation to spur significant advancement in the industry.

B. Proposed Legislation

The United States Senate has taken notice of the need for federal legislation. On February 27, 2020, Senator Angus King from Maine introduced the Battery and Critical Mineral Recycling Act of 2020 (the Act).[144] The Act works to incentivize battery recycling primarily through three grant programs: research and development; retail collection points; and matching funds for state and local governments.[145] Through research and development, the grants will support innovation in recycling processes and battery design, facilitate dismantling, and aid in the recovery of components and materials.[146] Additionally, the grants will bolster the number of collection points to increase the collection of used batteries.[147] Finally, the legislation will provide funds to match current state and local programs seeking to enhance battery collection, recycling, and reprocessing at a local level.[148]

Outside of the grant program, the Act would reauthorize the Department of Energy's Lithium-Ion Battery Recycling Prize competition through providing additional funds, direct the Administrator of the Environmental Protection Agency (EPA) to provide uniform best practices to be implemented by States and local leaders, develop a voluntary labeling program to identify collection points and direct the United States Secretary of Energy to convene a task force to establish producer requirements.[149] The Act would authorize appropriations of $30,000,000 for each fiscal year from 2021 through 2025 to accomplish these goals. The most recent action on the Act was the introduction and referral to the Senate Committee on Energy and Natural Resources.[150]

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143 The first phase was $1 million awarded to fifteen winners for concept development and incubation. The prize is currently in the second phase of prototype and partnering for which $2.5 million will be awarded to up to ten winners. Winners must partner with stakeholders to stimulate, verify, and validate concepts and processes. Finally, the third phase will include $2 million awarded up to four winners for pilot validation. This process includes building the battery recycling business model and demonstration of the process. *Id.*

144 Battery and Critical Mineral Recycling Act of 2020, S.3356, 166th Cong. §8 (2020)

145 Angus King, *With Energy Package on Senate Floor, King Introduces Groundbreaking Batter Recycling Legislation* (Mar. 3, 2020), https://www.king.senate.gov/newsroom/press-releases/with-energy-package-on-senate-floor-king-introduces-groundbreaking-battery-recycling-legislation#:~:text=The%20Battery%20and%20Critical%20Mineral,crucial%20to%20clean%20energy%20technology&text=Energy%20storage%20and%20electric%20vehicles,cobalt%2C%20nickel%2C%20and%20graphite [https://perma.cc/C49A-VYLM].

146 *Id.*

147 *Id.*

148 *Id.*

149 *Id.*

150 Battery and Critical Mineral Recycling Act of 2020, S.3356, 166th Cong. §8 (2020).

While all the actions of the Act will help further innovation, the Act lacks specific best practices and requirements. Instead, it directs other agencies to create rules and requirements while making the labeling program voluntary.[151] Both the EU and Japan have instated legislation with concrete requirements and thresholds for battery recyclability to spur recycling innovation and address the negative environmental, economic, and geopolitical issues surrounding Li-ion batteries.[152]

VI. THE EUROPEAN UNION MODEL

In response to projections that the share of annual EV sales in the European Union (EU) will reach twenty-three percent of global EV sales by 2030, equaling almost five million vehicles per year, the EU began promoting battery recycling through directives 2006/66/EC (batteries directive) and 2013/56/EU.[153] These directives impose minimum collection rates for retired batteries and give guidelines on calculating recycling efficiencies.[154] In addition, the European Commission created the European Battery Alliance in 2017 to establish a competitive and sustainable battery manufacturing sector.[155]

The Batteries Directive was adopted in 2006 by the European Commission and has been the subject of several revisions since that time, with the most recent revision occurring in 2013.[156] The directive enumerates the following specific restrictions on vehicle batteries.[157] First, the directive instates a ban on landfilling or incinerating batteries from vehicles and industrial equipment.[158] Next, the directive works to make producers responsible for making feasible battery collection by stating that "producers or third parties must set up schemes for collecting automotive waste batteries which are not collected via schemes set up under End-of-Life Vehicles Directive."[159] Further, the directive removes the financial burden from consumers while encouraging them to recycle and buy recycled batteries by asserting that consumers will not be charged for returning automotive waste batteries for non-commercial vehicles and that consumers shall not be forced to purchase new automotive batteries.[160] The directive classifies Li-ion batteries as industrial batteries instead of falling under the category of automotive batteries. The directive further places the burden on electric vehicle manufacturers by defining industrial batteries as "batteries that are designed for exclusively industrial or professional uses or used in any type of electric vehicle."[161] It continues

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[151] *Id.*
[152] Directive 2006/66/EC. European Parliament (2006); *See* Directive 2013/56/EU. European Parliament (2014); *See also End-of-Life Vehicle Recycling Law*, JAPANESE MINISTRY OF ECONOMY, TRADE AND INDUSTRY, (2006), https://www.meti.go.jp/policy/recycle/main/english/law/end.html [https://perma.cc/B92R-YYFX].
[153] Directive 2006/66/EC. European Parliament (2006); Directive 2013/56/EU. European Parliament (2013).
[154] *Id.*
[155] *Id.*; Gaines, *supra* note 53.
[156] *Id.*
[157] *Id.*
[158] Directive 2006/66/EC. European Parliament (2006).
[159] *Id.*
[160] Directive 2006/66/EC art. 8.
[161] Directive 2006/66/EC art. 9.

with specific rules that apply to all industrial batteries.[162] The directive restricts the use of mercury, which requires battery producers accept returned waste from end-of-life batteries.[163] Next, the directive requires that one hundred percent of industrial batteries be recycled and bans disposal in landfills or by incineration. Additionally, the directive requires that recycling processes achieve a minimum of fifty percent efficiency, and EU countries must recycle as much lead and cadmium as possible.[164] Finally, the directive requires that batteries must be labeled with a crossed-out wheeled bin to facilitate recycling. In contrast, batteries containing more than a given amount of mercury, cadmium, or lead must also be labeled with the appropriate chemical symbol.[165]

The Batteries Directive relates directive 2000/53/EC on end-of-life vehicles (ELV Directive) without prejudice, meaning that the directive does not change the current legislation.[166] The ELV Directive covers specific categories of vehicles, including their batteries, while the Batteries Directive applies to all batteries, including those inside automotive.[167]

The Batteries Directive establishes the principle of "producer responsibility" for electric vehicle manufacturers, similar to the ELV, placing responsibility for recycling and informing consumers of recycling practices on the producer as enumerated by the specific rules given by enumerating that car producers are seen as battery producers under the law.[168] The directive states, "a car producer is also regarded as a 'battery producer' in an EU member state if he/she places the battery on the market (inside the car) for the first time in that country on a professional basis."[169]

The ELV was adopted in 2005 to amend Council Directive 70/156/EEC regulating motor vehicles regarding their reusability, recyclability, and recoverability.[170] The legislation provides that new vehicles sold in the EU may be sold only if they "may be reused and/or recycled to a minimum of eighty five percent by mass or reused and/or recovered to a minimum of ninety five percent by mass."[171] This places the burden on manufacturers to have strategies in place to properly manage the reusability, recyclability, and recoverability requirements of the directive.[172] The directive ensures compliance of manufacturers within the EU by requiring them to receive a certificate of compliance issued by the national authority of their member state every two years.[173] The legislation carves out exceptions for special purpose and small series vehicles,

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162 Directive 2006/66/EC.
163 Directive 2006/66/EC art. 5.
164 Directive 2006/66/EC art. 15.
165 Directive 2006/66/EC art. 20.
166 Directive 2006/66/EC art. 27.
167 Directive 2006/66/EC art. 2.
168 *See generally* Directive 2006/66/EC.
169 Directive 2006/66/EC art.12.
170 Directive 2005/64/EC of the European Parliament and of the Council of 26 October 2005 on the type-approval of motor vehicles with regard to their reusability, recyclability and recoverability and amending Council Directive 70/156/EEC, 2005 O.J.(L 310) https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM%3An26102&qid=1604884384184[https://perma.cc/22RL-PQ84]
171 *Id.*
172 *Id.*
173 *Id.*

ensuring that public safety stays intact and small businesses are protected from the costs of innovation progression.[174] The act defines special purpose vehicles as armored cars and ambulances and small series vehicles as vehicles of which 500 or less are sold in the EU each year.[175]

The ELV ensures that companies innovate to protect the environment by prohibiting manufacturers from using hazardous substances such as lead, mercury, cadmium and hexavalent chromium.[176] Additionally, the ELV requires recycling through requiring EV manufacturers, importers, and distributors to provide systems to collect EV's and, when feasible, to collect used parts from repaired passenger cars.[177] The directive also requires owners of EVs delivered for waste treatment to receive a certificate of destruction to deregister the vehicle.[178] However, in order to keep the burden on consumers minimal, the directive states that manufacturers must provide a significant part of the costs of delivering an EV to a waste treatment facility.[179] The directive states that a vehicle owner should not incur any expenses when delivering an EV to an authorized waste treatment facility, except where the engine is missing or the EV is full of waste.[180]

The ELV requires that waste treatment facilities apply for a permit or register with the competent authorities of the EU country where they are located.[181] The directive promulgates a system for dealing with hazardous waste by mandating that EV's are first stripped before further treatment takes place and that hazardous substances and components be removed and separated.[182] The directive focuses specifically on the potential reuse, recovery, or recycling of the waste.[183] This legislation also applies to all passenger vehicles and small trucks but not to big trucks, vintage vehicles, special-use vehicles and motorcycles similar to the batteries directive.[184]

VII. JAPANESE LEGISLATION

Japanese Automobile Recycling Law, passed in July 2002 and put into effect in April 2005, also ensures environmentally friendly recycling practices by stipulating that every end-of-life vehicle must be dismantled and recycled in an eco-friendly manner.[185] The Japanese government ensures that recycling laws are followed through the IT manifesto, which

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[174] *Id.*
[175] *Id.*
[176] End-of-Life Vehicles. European Union. https://ec.europa.eu/environment/topics/waste-and-recycling/end-life-vehicles_en [**https://perma.cc/2JS4-V585]**
[177] Directive 2005/64/EC of the European Parliament and of the Council of 26 October 2005 on the type-approval of motor vehicles with regard to their reusability, recyclability and recoverability and amending Council Directive 70/156/EEC, 2005 O.J.(L 310) https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM%3An26102&qid=1604884384184[https://perma.cc/22RL-PQ84]
[178] Directive 2000/53/EC art.5. European Parliament (2000).
[179] *Id.*
[180] *Id.*
[181] *Id.*
[182] *Id.*
[183] *Id.*
[184] *Id.*
[185] End-of-Life Vehicle Recycling Law. Japanese Ministry of Economy, Trade and Industry. (2006) https://www.meti.go.jp/policy/recycle/main/english/law/end.html **[https://perma.cc/B92R-YYFX].**

is a computer governed system that tracks the passage of every end-of-life vehicle in Japan.[186] Dismantlers and shredding operators are obligated by law to receive a permit from their local municipal office, while ELV collectors and fluorocarbon operators are to be noticed.[187]

Although, the Japanese model places some responsibility on the consumer by obligating all vehicle owners to pay a recycling fee in advance or vehicle purchase, the Japanese system places the majority of the responsibility on the manufacturer.[188] In Japan, the manufacturer of the vehicle is responsible for disposal and dismantling of the vehicle in a way that does not harm the environment.[189] Under the legislation, the vehicle manufacturer is responsible of disposing of fluorocarbons and airbags from an end-of-life vehicle that are difficult to dispose of in an environmentally friendly and economic manner.[190]

VIII. COMPARING THE EUROPEAN AND JAPANESE LEGISLATION

Although the European and Japanese legislation differ in many ways, they are similar in three main areas that allow the legislation to function in a viable manner. First, models require that all electric vehicles be recycled. Second, both models include systems for ensuring that all vehicles are recycled. The European model ensures that policies are followed through requiring manufacturers to acquire certificates of compliance from certified EU state agencies, while the Japanese model regulates through an automated computer system. Third, both models place much of the financial and systemic burden on manufacturers. Although the European model completely takes the burden off consumers by specifying that no vehicle owners shall pay any recycling fees, and Japan conversely requires a recycling fee for consumers, the EU requires manufacturers to create a recycling plan, label batteries to communicate recyclability, and take responsibility for accepting returned waste batteries from consumers. Japan similarly requires that the vehicle manufacturer is responsible for disposing of auto-shredding residues, fluorocarbons, and airbags from end-of-life vehicles that are difficult to dispose of in an environmentally friendly and economic manner.[191]

IX. PROPOSED LEGISLATION RECOMMENDATIONS

The United States should follow the example of the EU and Japan and enact legislation that requires all electric vehicles be recycled and include a system to ensure that the vehicles are recycled, which places the burden on manufactures.

In order to ensure that companies utilize the recycling process, the process must meet three main objectives: high product quality and reliability; competitive collection and recycling costs; and low

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[186] *Id.*
[187] *Id.*
[188] *Id.*
[189] *Id.*
[190] *Id.*
[191] *Id.*

environmental footprint.[192] Currently, the proposed Battery and Critical Mineral Recycling Act of 2020 has a specific plan for financing; however, the bill lacks specific regulations requiring all electric vehicles be recycled, enumerating percentages of certain rare earth minerals, and delineating recycling costs to either the manufacturer or the consumer, which have been pivotal in encouraging innovation in the European Union and Japan. While the current bill is necessary and should be passed as quickly as possible, another bill must be introduced adding these additional regulations into law.

A. Set Requirement that 100% of EV's be Recycled with Specific Rules for Recycling

Requiring that all electric vehicles be recycled creates a precedent that there are no exceptions to recycling. The specific rules following this precedent ensure that the manufacturers know the expectations in carrying out that recycling. The United States should adopt the specific rules from the EU that batteries cannot be disposed of in landfills or by incineration, that the recycling processes used must achieve a minimum of fifty percent efficiency, and that EU countries must recycle as much lead and cadmium as possible.[193] This will help ensure that companies do not continue to dump waste in landfills resulting in environmental pollution. Additionally, the regulation sets a minimum standard for the recycling practices, which must be used to address the issue of a lack of universal standards.

In addition to the specifics given by the European Union, US legislation should require that recycling restore materials to their original high purity and battery grade condition.[194] Currently, many recyclers downcycle their materials to a grade unable to be used for EV Li-ion battery manufacturing and sell the materials to other industries because either the process does not allow them to recycle to the grade necessary or the recyclers will turn a larger profit selling to another sector.[195] Although this process of downgrading material is preferable to sending end-of-life batteries to landfills, the practice does not relieve the supply chain issues for EV batteries.[196] To decrease reliance on mining and virgin materials, recyclers must be able to offer reliable and high-grade recycled materials back to battery manufacturers.[197]

Recycling investments should be driven by the promise of profits from sales of recycled materials.[198] In order to achieve this, the market price for recycled materials must cover the cost of collecting, transporting, storing, and processing the used materials along with returning a profit for the operator.[199] Additionally, the profits must be competitive with the cost of virgin materials in order for battery manufacturers to purchase recycled

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[192]Beaudet, *supra* note 40.
[193]*Id.;* Directive 2006/66/EC art. 15.
[194] *Id.*
[195] *Id.*
[196] *Id.*
[197] *Id.*
[198] *Id.*
[199] *Id.*

materials over raw materials.[200] Unfortunately, with current methods, the costs of recycling are often much higher than the cost of mining and refining raw materials.[201] This is a deterrent for investment into recycling research and practices.[202] Additionally, the volatility of the raw material market makes it difficult to predict supply and demand.[203] These inconsistencies highlight a need for government support to balance the market and make it worthwhile to investors and companies to focus on recycling.[204]

The primary reason for recycling is to reduce environmental impacts preproduction and postproduction of Li-ion batteries the environmental of recycling should not be greater than virgin materials.[205] Currently, recycling large amounts of electrical and thermal energy can generate secondary toxic gas emissions and water contaminants.[206] Additionally, collecting and transporting used batteries can use substantial amounts of energy.[207] Therefore, the entire process of recycling needs to be streamlined and improved to make the process economically and environmentally.[208]

B. Set Regulatory Scheme for EV Manufacturers

The United States should instate a regulatory scheme focused on the principle of producer responsibility as highlighted in both the EU and Japanese models, putting the responsibility for recycling and informing consumers of recycling practices on the manufacturers. A hybrid of the EU and Japanese model will likely perform best in the United States. The United States already has the necessary agencies, such as the Department of Energy mentioned in Senator King's Battery and Critical Mineral Recycling Act and state Departments of Transportation, which have vehicle registration systems. The Department of Energy should require that car manufacturers acquire a certificate of compliance like in the EU, where manufacturers must renew their certification with a verified EU state agency every two years. Additionally, manufacturers and consumers should be required to register the car and subsequent recycling with their respective state Departments of Transportation to record all vehicle recycling like the computer system which monitors vehicles in Japan.

Policies relating to environmental issues and motor vehicles are not unheard of in the United States when.[209] The Clean Air Act establishes regulations for vehicle greenhouse gas emission in the United States.[210] The Act imposes penalties on companies who do not comply with the standards.[211] For example, in 2016 the Justice Department sued

[200] *Id.*
[201] *Id.*
[202] *Id.*
[203] *Id.*
[204] *Id.*
[205] *Id.*
[206] *Id.*
[207] *Id.*
[208] *Id.*
[209] 42 U.S.C. § 7401, *et seq.* (1970).
[210] *Id.*
[211] *Id.*

Volkswagen on behalf of the Environmental Protection Agency for up to $46 billion for violations of the Clean Air Act.[212] The complaint alleged that Volkswagen equipped 2.0 and 3.0 diesel engine vehicles caused pollution in excess of the standards.[213] Since this lawsuit, Volkswagen has updated the impacted models to comply with standards. The regulations were effective in holding offending companies accountable and forcing manufacturers to modify their supply chains to reduce emissions. Similarly, the United States should require specific battery recycling percentages put in place by both Japan and China to place the compliance burden on manufacturers and aid in creating an economic and environmentally viable Li-ion battery recycling process.

A potential drawback of shifting the burden to manufacturers is that it will likely add extra costs and therefore take away from the demand for EV's. Policymakers need to balance the need to create a sustainable closed-loop supply chain for Li-ion batteries with the need to encourage the transition to electric powered transport. The way to combat this is to introduce the legislation over a period. The proposed legislation of the Battery and Critical Mineral Recycling Act would introduce funding over a four-year period. Similarly, legislation instating regulations and penalties would need to be instituted over a period instead of going into effect immediately. Policymakers will need to determine what is a reasonable period.

X. CONCLUSION

The EU and the United States have a long and enduring political, economic, and cultural relationship; therefore, it follows that the United States should take notice of the policy adoptions by the EU in relation to Li-ion battery recycling, just as Japan has done with a few modifications.[214] This is reflected in close transatlantic relations and through similar policy decisions and exemplified by the fact that the United States and EU have a yearly meeting transatlantic business dialogue, in which EU and United States business leaders and administration representatives meet to develop policy recommendations.[215] Economic relations is one of the main reason that Japan decided to adopt regulations. The strict European Union model influenced Japan to add the regulations the country has regarding automobile recycling as many of their cars are sold in Europe.[216]

Additionally, the United States should enact legislation that requires all EV's be recycled and include a system that places the burden

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[212] David Shepardson, *VW Blasted for Shielding Emissions Documents from U.S. Probe*, REUTERS (Jan. 8, 2016), https://www.reuters.com/article/us-volkswagen-emissions-emails-idUSKBN0UM1WZ20160108 [https://perma.cc/3V9D-8NXY].

[213] *Id.*

[214] *The European Union and the U.S.: Glob. Partners, Glob. Resp.*, EUR. COMM'N (2006), http://www.eeas.europa.eu/archives/docs/us/docs/infopack_06_en.pdf [https://perma.cc/33QM-72HD].

[215] *Id.*

[216] Shin-ichi Sakai et al., An International Comparative Study of End-of-Life Vehicle (ELV) Recycling Systems, J. MATER. CYCLES WASTE MGMT. 16, 1-20 (2014).

on manufactures in order to avoid negative environmental impacts similar to those which prompted both the EU and Japan stricter regulation. Serious talks about the disposal of EV's began in Europe in the 1990's prompted by Germany's projection that they would run out of landfill space by the year 2000.[217] By 1990, a resolution was formed by the European Counsel that measures relevant EVL's consolidated on a European Community level.[218] By the mid 1990's companies such as BMW began researching and incorporating the idea of recyclability in their current models.[219] In 2000 a directive was passed by the EU regarding the treatment of end-of-life vehicles.[220] All companies, that were manufacturing and or selling automobiles in the EU were made to follow and comply with the guidelines stated in the directive.[221] Additionally, during the Teshima incident in Japan, one industrial waste disposal company burnt and illegally disposed of 500,000 tons worth of ELV shredder residue on Teshima between the late 1970 and 1991.[222] Shredder residue is composed of materials shredded from car seats, bumpers, glass, and other non-metallic components of the car. It contains hazardous chemicals including dioxins, which in the case of Teshima contaminated the Seto Island Sea.[223] When a small car with a 1,500cc engine is dismantled, about 200 kg of shredder residue is generated. Considering that in the year 2008, Japan produced under 3.58 million ELVs, the problem of illegally disposed shredder dust in Teshima can be seen.[224] Efforts to relocate and refine the shredder residue in Teshima have been in action at a nonferrous metal refining factory in Naoshima Island since 2002.[225] This is estimated to take until 2016.[226]

For the environmental, economic, and geopolitical reasons set out above the United States should enact legislation that requires all EV's be recycled and include a system to ensure that the vehicles are recycled which places the burden on manufacturers.

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[217] Paul Nieuwenhuis & Peter Wells, From manufacturers to responsible mobility providers, THE AUTOMOTIVE INDUSTRY AND THE ENVIRONMENT. 50-61 (2003).
[218] Resolution 90/C 122/02. Council Resolution of 7 May 1990 on waste policy. OFFICIAL JOURNAL OF THE EUROPEAN COMMUNITIES. https://op.europa.eu/en/publication-detail/-/publication/5223e701-4eb3-4994-952b-cf7ce521a32c/language-en [https://perma.cc/AGH7-SWNB].
[219] *BMW: A PROACTIVE APPROACH TO VEHICLE RECYCLING*, UNITED STATES ENV'T PROTECTION AGENCY (1992), https://www.epa.gov/sites/default/files/2017-12/documents/ee-0229a_acc.pdf [https://perma.cc/H932-4KZG].
[220] Sakai, *Supra* note 216
[221] *Id.*
[222] Kagawa Takamatsu, *Teshima Cleanup Pledge Ends Dispute*, THE JAPAN TIMES (June 7, 2000), https://www.japantimes.co.jp/news/2000/06/07/national/teshima-cleanup-pledge-ends-dispute/ [https://perma.cc/PR6M-8C2B].
[223] *Id.*
[224] *Id.*
[225] *Id.*
[226] *Id.*